

ENERGY REPORT

ENERGY ENGINEERING ANALYSIS PROGRAM

ENERGY SURVEY OF BOILER AND CHILLER PLANTS

YUMA PROVING GROUND, ARIZONA

Oct. 94

19971023 111

PREPARED FOR

**DEPARTMENT OF THE ARMY
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
SACRAMENTO, CALIFORNIA**

PREPARED BY

**KELLER & GANNON
ENGINEERS • ARCHITECTS
1453 MISSION STREET, SAN FRANCISCO, CA 94103**

CONTRACT NO. DACA 05-C-92-0155

DISTRIBUTION STATEMENT A
Approved for public release
Distribution Unlimited

DTIG QUALITY INSPECTED 2

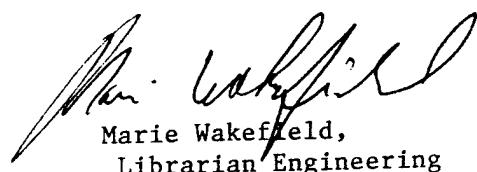


DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES, CORPS OF ENGINEERS
P.O. BOX 9005
CHAMPAIGN, ILLINOIS 61826-9005

REPLY TO
ATTENTION OF: TR-I Library

17 Sep 1997

Based on SOW, these Energy Studies are unclassified/unlimited.
Distribution A. Approved for public release.



Marie Wakefield,
Librarian Engineering

Table of Contents

	Page
1.0 Executive Summary	1-1
1.1 Introduction	1-1
1.2 Energy Conservation Analyses	1-1
1.3 ECIP Project Developed	1-1
1.4 Conversion to Non-Chlorofluorocarbon Refrigerants	1-2
2.0 Introduction	2-1
2.1 Purpose	2-1
2.2 Scope	2-1
2.3 Methodology	2-1
3.0 Description of Installation	3-1
3.1 General Site Data	3-1
3.2 Chiller Plants	3-1
3.3 Boiler Plant	3-3
4.0 Energy Conservation Evaluations	4-1
4.1 Life Cycle Cost Analysis Assumptions	4-1
4.2 Construction Cost Estimate Methodology	4-2
4.3 Utility Rebate Programs	4-3
4.4 Energy Conservation Opportunities Studied	4-3
4.5 Recommended Energy Conservation Projects	4-8
5.0 Conversion to Non-Chlorofluorocarbon Refrigerants	5-1
5.1 Introduction	5-1
5.2 Yuma Proving Ground Chillers	5-3
5.3 Recommendations for Yuma Proving Ground Chillers Surveyed	5-6
6.0 Evaluation of Energy Monitoring and Control System	6-1
6.1 Existing System	6-1
6.2 Energy Monitoring and Control System Evaluation	6-1
6.3 Energy Monitoring and Control Features	6-2
Appendix A Scope of Work and Minutes of Project Meetings	
Appendix B Field Data Summary	
Appendix C Boiler Efficiency Improvement Project Calculations	
Appendix D Boiler Plant Efficiency Calculation Methods	
Appendix E Chiller Performance Data/Calculations	
Appendix F Chiller Retrofit Calculations	
Appendix G Lighting Data and Energy Calculations	
Appendix H Lighting Retrofit Calculations	
Appendix I Energy Monitoring and Control System Calculations	
Appendix J Outline of Operations and Maintenance Instruction	

List of Figures

	Page	
Figure 3-1	Yuma Proving Ground General Location Map	3-4
Figure 3-2	Building 451 Chilled Water Flow Diagram	3-5
Figure 3-3	Building 506 Flow Diagram	3-6
Figure 3-4	Building 2105 Chilled Water Flow Diagram	3-7
Figure 3-5	Building 3482 Flow Diagram	3-8
Figure 3-6	Building 3490 Chilled Water Flow Diagram	3-9
Figure 3-7	Building 3510 Flow Diagram	3-10

List of Tables

	Page	
Table 1-1	Summary of ECO Evaluations	1-3
Table 1-2	Recommended Energy Conservation Opportunities	1-4
Table 1-3	Energy Conservation Opportunities Not Recommended	1-5
Table 1-4	Non-Chlorofluorocarbon Refrigerant Conversion Recommended	1-6
Table 3-1	Summary of Energy Survey Chillers	3-3
Table 4-1	Summary of ECO Evaluations	4-9
Table 4-2	Recommended Energy Conservation Opportunities	4-10
Table 4-3	Energy Conservation Opportunities Not Recommended	4-11
Table 5-1	Refrigerant Production Table (Montreal Protocol Production Caps)	5-2
Table 5-2	Short-Term and Long-Term Refrigerant Solutions	5-3
Table 5-3	Summary of Existing Chiller Data	5-8
Table 5-4	Recommendations for Study Chillers	5-9
Table 6-1	EMCS Energy Savings Summary	6-5

1.0 Executive Summary

1.1 Introduction

This report summarizes all work for the Energy Survey of Boiler and Chiller Plants, Energy Engineering Analysis Program (EEAP) at U.S. Army Yuma Proving Ground, Arizona, authorized under Contract DACA05-92-C-0155 with the U.S. Army Corps of Engineers, Sacramento District, California.

The purpose of this study is to develop projects and actions that will reduce facilities energy consumption and operating costs at Yuma Proving Ground. Implementation of these projects will contribute to achieving the goal of the Army Facilities Energy Plan of a reduction in energy consumption per square foot of building floor area of 20 percent by FY2000 from FY1985 baseline levels.

The survey and evaluation effort was limited to chillers and direct expansion cooling units in Buildings 451, 506, 2105, 3482, 3490, and 3510 and boilers in Building 506.

1.2 Energy Conservation Analysis

A summary of all potential energy conservation opportunities (ECOs) investigated is presented in Table 1-1. This table includes a matrix of reasons for eliminating ECOs from further consideration. A summary of analysis results for recommended ECOs is presented in Table 1-2, and a summary of analysis results for ECOs rejected is presented in Table 1-3.

1.3 ECIP Project Developed

An ECIP-qualifying project covering energy improvements in the surveyed facilities was developed that includes the following retrofit measures:

- a. Replace two steam boilers with one modular hot water boiler system in Building 506.
- b. Install chilled water temperature reset controls on three chillers (one in Building 506 and two in Building 2105).
- c. Replace the converted 45-ton glycol chiller for ice-on-coil system at Building 506 with an efficient unit designed for cold temperature application.
- d. Install duty cycling controls on four chillers (one in Building 451 and three in Building 3490).

- e. Modify lighting fixtures and install lighting controls as follows:
 - (1) Retrofit fluorescent fixtures with electronic ballasts and T8 lamps in Buildings 451, 506A, 506B, 506C, 2105 and 3490.
 - (2) Retrofit 4-lamp fluorescent fixtures with 3-lamp electronic ballasts, T8 lamps and specular reflectors in Buildings 457, 506B, 2105 and 3490.
 - (3) Replace incandescent fixtures with surface mounted T8 and compact fluorescent fixtures in Buildings 451, 506A and 506B.
- f. Install occupancy sensors (ceiling or wall-switch mounted) in Buildings 451, 506A, 506B, 2105 and 3490.
- g. Install additional (explosion-proof) light fixture switching in Building 3482.

The following ECIP project data is taken from the DD Form 1391 life cycle cost analysis summary sheet (note that more up-to-date criteria and discount factors are used to prepare funding documents, thus, results may not be the same as presented in this report):

Construction cost (including SIOH, design and utility rebates)	\$632,257
Annual energy savings	
• Electricity	3,321 million Btu
• No. 2 fuel oil	466 million Btu
• Liquified petroleum gas (LPG)	578 million Btu
Annual dollar savings	\$119,952
Savings-to-investment ratio (SIR)	2.64
Simple payback period	5.3 years
Analysis date	January 1994

1.4 Conversion to Non-chlorofluorocarbon Refrigerants

In response to the production phaseout of CFCs and HCFCs as mandated by the Montreal Protocol, the scope of the study included an analysis of conversion to non-CFC refrigerants for the surveyed chillers. Recommendations to contain existing refrigerants, retrofit with HFC-type refrigerants, or completely replace chillers, along with associated costs, are summarized in Table 1-4.

Table 1-1
Summary of ECO Evaluations

No.	Description of ECO	SIR Greater Than 1.0	SIR Less Than 1.0	Recommended Project
Building 506 Boiler Efficiency Improvements				
B1	High Efficiency Burners and O ₂ Trim Controls	✓		
B2	Install Engineered Turbulators in Fire Tubes	✓		
B3	Automatic Boiler Blowdown with Heat Recovery	✓		
B4A	New Modular Boilers for Heating and Domestic Water	✓		✓
B4B	New Modular Boilers for Domestic Water Only		✓	
Cooling Equipment ECOs				
Chilled Water Temperature Reset (Buildings 506 C-1, 2105 C-1 and C-5)		✓		✓
Chilled Water Temperature Reset (Buildings 451, 2105 C-2, 3490 C-1, C-2 and C-3)			✓	
Replace Glycol Chiller at Building 506		✓		✓
Electronic Expansion Valves (Buildings 3482 and 3510)			✓	
Optimize Cooling Tower Control (Condenser Water Temperature)			✓	
Manifold Chillers C-1, C-2 and C-3 at Building 3490		✓		✓
Duty Cycling Controls, Demand Limiting		✓		✓
Shading Air Cooled Condensers			✓	
Evaporative Precooling			✓	
Lighting and Control ECOs				
A	Retrofit: 1-Lamp Electronic Ballast and T8 Lamp	✓		Most
B	Retrofit: 2-Lamp Electronic Ballast and T8 Lamps	✓		✓
C	Retrofit: 3-Lamp Electronic Ballast and T8 Lamps	✓		✓
D	Retrofit: 4-Lamp Electronic Ballast and T8 Lamps	✓		Most
E	New Fixture: 1-Lamp Electronic Ballast and T8 Lamp		✓	
F	New Fixture: 2-Lamp Electronic Ballast and T8 Lamps	✓		Most
G	New Fixture: 3-Lamp Electronic Ballast and T8 Lamps — Explosion Proof		✓	
H	Retrofit: 3-Lamp Electronic Ballast and T8 Lamps and Specular Reflector	✓		✓
I	Retrofit: Occupancy Sensor Lighting Control — Ceiling Mounted	✓		✓
J	Retrofit: Occupancy Sensor Lighting Control — Auto. Wall Switch	✓		✓
K	New Fixture: 2-Lamp Compact Fluorescent, 2 x 13W/ST4	✓		✓
L	New Fixture: 2-Lamp Electronic Ballast and T8 Lamps, 2' Surface Mount	✓		✓
M	Install Switching for Assembly Rooms — Building 3482	✓		✓
Notes: Only one Boiler Efficiency project group may be implemented: (B1, B2 and B3), B4A or B4B. B4A is recommended.				
Lighting and control ECOs where recommendations are shown as "Most" are evaluated separately for each building; buildings in which the ECOs show SIRs > 1 are recommended.				

Energy Survey of Boiler and Chiller Plants
Yuma Proving Ground, Arizona

Revised October 1994

Table 1-2
Recommended Energy Conservation Opportunities

Project / Number	Description	Electric Savings kW	Fuel MBTU/Yr kW/Hr/Yr	Fuel LPG Distillate	Energy Cost Saved \$/Year	O&M Cost Saved LCC 4 \$/Year	Investment \$/	SIR	Economic Measure Payback AIR
Recommended Building 506 Boiler Efficiency Improvement Projects									
B1	New Burners & O2 Trim	-	330	346	\$6,923	\$87,045	(\$1,320)	1.17	11.1
B2	Engineered Turbulators	-	164	163	\$3,371	\$42,348	(\$5,574)	2.188	0.8
B3	Auto-Blowdown w/ Heat Recovery	-	3	2	\$49,61	\$622	\$6,798	73,011	16.8
Totals for B1, B2 & B3			487	611	\$10,344	\$130,013	\$4,959	153,260	4.27
B4A	Modular Boilers for Heating & DHW	-	466	578	\$10,435	\$131,662	\$17,820	\$191,387	\$122,560
B4B	Modular Boilers for DHW Only	-	200	247	\$4,467	\$66,354	(\$1,980)	(\$21,285)	\$73,923
								0.47	29.7
									-0.6%
Note: Boilers in building 506 are dual fueled, alternating between No. 2 Fuel Oil (Distillate) and LPG; boilers serve building 506 only.									
Recommendation: Implement B4A - Each of the above project groupings are mutually exclusive, e.g., project B4A cannot be economically justified if the group of B1, B2 & B3 are implemented.									
Recommended Cooling Equipment Energy Conservation Opportunities Evaluated									
A	Chilled Water Temperature Reset (506 C-1, 2105 C-1 & C-5)	146,584	-	-	\$12,168	\$137,481	(\$1,584)	(\$17,012)	\$30,304
B	Replace Glycol Chiller 506 C-2	80,000	-	-	\$6,940	\$75,032	-	-	\$62,866
C	Manifold Chiller C-2 & C-3 at Building 3480	92,825	-	-	\$7,704	\$87,060	(\$1,320)	(\$14,177)	\$57,321
D	Duty Cycling Controls	36.8	-	-	\$1,164	\$13,157	(\$1,132)	(\$1,418)	\$6,524
Total of Recommended Cooling Equipment ECOs		36.8	319,409	-	-\$27,675	\$312,730	(\$3,036)	(\$32,606)	\$166,766
								1.79	6.36
Recommended Lighting & Control Energy Conservation Opportunities Evaluated									
A	1-Lamp Electronic Ballast & T8 Lamp (2105S1 & 506A)	2.0	13,693	-	\$1,163	\$13,031	(\$1,04)	(\$1,116)	\$7,886
B	2-Lamp Electronic Ballast & T8 Lamps	50.3	213,214	-	-\$17,697	\$189,973	(\$1,580)	(\$17,073)	\$119,000
C	3-Lamp Electronic Ballast & T8 Lamps	18.2	72,093	-	\$5,984	\$67,616	(\$602)	(\$6,463)	\$36,981
D	4-Lamp Electronic Ballast & T8 Lamps (506A & C)	2.3	7,888	-	\$653	\$7,379	(\$72)	(\$770)	5,398
F	2-Lamp Electronic Ballast & T8 Lamps (506B)	10.6	35,226	-	\$2,924	\$33,039	\$6,132	\$65,854	\$32,580
H	3-Lamp Electronic Ballast & T8 Lamps & Specular Reflector	20.9	76,626	-	\$6,277	\$70,930	(\$1,09)	(\$1,176)	\$34,379
I	Ceiling Mounted Sensor Switch (2105, 3490, 506)	-	66,063	-	\$6,313	\$71,240	\$0	\$0	\$31,097
J	Automatic Wall Sensor Switch (451, 3490, 2105)	-	61,403	-	\$5,097	\$57,594	\$0	\$0	\$20,560
K	2-Lamp Compact Fluorescent 2 x 13W/5T4	4.1	16,076	-	\$1,334	\$16,078	\$1,003	\$10,769	\$13,573
L	2-Lamp Elect. Ballast & T8 Lamps, 2' Surface Mount	16.6	51,587	-	\$4,282	\$48,384	\$6,138	\$67,389	\$36,279
M	Install Light Switching for Assembly Rooms - Bldg 3482	-	30,680	-	\$2,546	\$28,775	\$0	\$0	\$15,220
Total of Recommended Lighting & Control ECOs		123.6	663,735	-	-\$54,260	\$613,138	\$12,796	(\$137,426)	\$362,942
								2.13	6.27
GRAND TOTAL OF RECOMMENDED ECOs		160.4	973,144	466	578	992,370	\$1,057,530	(\$27,580)	\$286,205
Includes Project B4A only from Boiler Efficiency Improvements									

Energy Survey of Boiler and Chiller Plants Yuma Proving Ground, Arizona

Revised October 1994

Table 1-3
Energy Conservation Opportunities Not Recommended

Project / Number	Description	Electric Savings kW	Energy Cost Saved \$/Year	O&M Cost Saved \$/Year	Investment LCC \$	Investment LCC \$	SIR	Economic Measures Payback	AIRR
Cooling Equipment Energy Conservation Opportunities Not Recommended									
Chilled Water Temperature Reset (451, 2105 C-2, 3480)	- 8.225	\$833	\$7.712	-	-	\$50,505	0.15	73.98	-7.81%
Optimize Cooling Tower Control (Condenser Water Temperature Reset)									
Shade Air Cooled Condensers from Sunlight									
Evaporative Precooling of Air Cooled Condenser Air									
Lighting & Control Energy Conservation Opportunities Not Recommended									
A 1-Lamp Electronic Ballast & 18 Lamp (2105N, S2 & 3490)	0.80	3,567	\$298	\$3,345	(\$31)	(\$334)	\$4,284	0.70	16.17
D 4-Lamp Electronic Ballast & 18 Lamps (2105S2 & 506B)	1.11	3,075	\$255	\$2,884	(\$101)	(\$1,083)	\$2,976	0.61	19.27
E New Fixture for Lighting ECO (511, 508, 2105 & 3490)	2.74	10,898	\$897	\$10,135	(\$80)	(\$863)	\$46,326	0.20	56.74
F 2-Lamp Electronic Ballast & 18 Lamps (451)	0.30	1,098	\$91	\$1,031	\$170.6	\$1,832	\$3,708	0.77	14.15
G 3-Lamp Electronic Ball. & 18 Lamps - Explosion Proof (3482 & 3510)	28.91	64,424	\$5,332	\$60,253	\$2,155	\$23,140	\$632,295	0.13	84.46
I Ceiling Mounted Sensor Switch (506A)	0.00	3,847	\$319	\$3,608	\$0	\$0	\$7,323	0.49	22.94
J Automatic Wall Sensor Switch (506A & B)	0.00	19,899	\$1,660	\$18,758	\$0	\$0	\$40,890	0.46	24.63

Table 1-4
Non-Chlorofluorocarbon Refrigerant Conversion Recommendations (1)

Building Number	Unit Description (2)	Contain Refrigerant	Replace Refrigerant	Replace Unit	Recommended Investment (3)	Explanation
451	55 Ton A/C Reciprocating Chiller	\$ 12,500	-	\$ 60,574	\$ 14,000	Unit is now only 7 years old. Contain refrigerant until a replacement unit is needed.
506	220 Ton W/C Centrifugal Chiller C1	\$ 12,500	\$ 17,680	\$ 159,424	\$ 178,555	Unit is now 20 years old and is due for replacement at this time.
506	45 Ton A/C Reciprocating Glycol Chiller C2	\$ 12,500	-	\$ 55,898	\$ 62,606	Analysis shows that replacing this unit now is the most cost effective choice.
2105	125 Ton W/C Centrifugal Chiller C1	\$ 12,500	\$ 16,728	\$ 145,558	\$ 163,025	Unit is now 17 years old and is due for replacement at this time.
2105	40 Ton W/C Reciprocating Chiller C2	\$ 12,500	-	\$ 46,792	\$ 52,408	Unit is now 17 years old and is due for replacement at this time.
2105	125 Ton W/C Centrifugal Chiller C5	\$ 12,500	\$ 16,728	\$ 145,558	\$ 14,000	Unit is only 10 years old. Contain refrigerant until a replacement unit is needed.
3482	62 Ton W/C Reciprocating DX Unit	\$ 12,500	-	\$ 53,992	\$ 60,471	Unit is now 24 years old and is due for replacement at this time.
3490	25 Ton A/C Reciprocating Chiller C1	\$ 12,500	-	\$ 32,138	\$ 14,000	Unit is now only 7 years old. Contain refrigerant until a replacement unit is needed.
3490	50 Ton A/C Reciprocating Chiller C2	\$ 12,500	-	\$ 57,312	\$ 14,000	Unit is now only 7 years old. Contain refrigerant until a replacement unit is needed.
3490	100 Ton A/C Reciprocating Chiller C3	\$ 12,500	-	\$ 112,800	\$ 14,000	Unit is now only 7 years old. Contain refrigerant until a replacement unit is needed.
3510	40 Ton W/C Reciprocating DX Unit	\$ 12,500	-	\$ 38,932	\$ 14,000	Unit was converted to HFC-134a in 1993. Retrofit refrigerant containment equipment.
Total Probable Construction Cost						\$ 601,064

Notes:

1. Recommended options are displayed in **Bold-Face** type.
2. Condenser types: A/C = Air Cooled; W/C = Water Cooled
3. Investment includes construction costs plus 6% for SIOH and 6% for design.

**Life Cycle Cost Analysis Summary
Energy Conservation Investment Program (ECIP)**

Location: Yuma Proving Ground, Arizona Region No. 4 Project No.
 Project Title: ECIP Facility Energy Improvements - Total Project Fiscal Year FY96
 Analysis Date: January 1994 Economic Life: 15 & 20 Years Preparer: KELLER & GANNON

1. Investment Costs

A. Construction Costs	\$ 565,547		
B. SIOH	\$ 33,933		
C. Design Cost	\$ 33,933		
D. Total Cost (1A + 1B + 1C)	\$ 633,413		
E. Salvage Value of Existing Equipment		\$ 1,206	
F. Public Utility Company Rebate		\$0	
G. Total Investment (1D-1E-1F)			\$632,207

2. Energy Savings (+)/Cost(-):

Date of NISTIR 85-3273 Used for Discount Factors: October 1993

Energy Source	Cost \$/MBTU(1)	Saving MBTU/Yr(2)	Annual \$ Savings(3)	Discount Factor(4)	Discounted Savings(5)
A. Elec. 15 Year	\$24.32	2,231	\$54,260	12.49	\$677,707
B. Elec. 20 Year	\$24.32	1,090	\$26,511	15.64	\$414,631
C. Dist 20 Year	\$13.25	466	\$6,174	17.47	\$107,866
D. LPG 20 Year	\$7.37	578	\$4,263	19.21	\$81,884
E. Other					
F. Demand Savings	\$31.68/kW	36.75	kW	\$1,164	15.64
G. Total		4,366	\$92,372		\$18,210
					\$1,300,298

Demand savings are based on \$1.98/kW/Mo @ 6 Months + 10 times rate for 1 Mo.; 20 year life.

3. Non Energy Savings (+) or Cost (-):

A. Annual Recurring (+/-)	15 Years	\$12,796	\$27,580	Total per Year
	20 Years	\$14,784		
(1) Discount Factor (Table A)	15 Years		11.85	
	20 Years		14.74	
(2) Discounted Savings/Cost (3A x 3A1)				\$369,544

B. Non Recurring Savings (+) or Cost (-)

Item	Savings(+) Cost(-)(1)	Year of Occur. (2)	Discount Factor(3)	Discounted Savings(+)Cost(-)(4)
a.				
b.				
c.				
d. Total				

C Total Non Energy Discounted Savings (3A2 + 3Bd4) \$369,544

4. First Year Dollar Savings (2G3 + 3A + (3Bd1/Years Economic Life)): \$119,952

5. Simple Payback (1G/4): 5.27 Years

6. Total Net Discounted Savings (2F5 + 3C): \$1,669,842

7. Savings to Investment Ratio (SIR) 5/1G: 2.64